Use of Natural Analogs in the U.S. Nuclear Waste Program

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RESEARCH OBJECTIVES

The U.S. Department of Energy's Repository Safety Strategy for a potential nuclear waste repository at Yucca Mountain, Nevada, rests upon four repository system attributes: (1) limited water contacting waste packages; (2) long waste package lifetimes; (3) slow rate of radionuclide release; and (4) concentration reduction of radionuclides during transport. For each of these attributes, natural analog studies are applied to understand the bounds of processes occurring over long time periods and to test and build confidence in conceptual and numerical models of those processes. Natural analogs refer to natural or anthropogenic (human-produced) systems in which processes expected to occur in a nuclear waste repository have occurred over long time periods and large spatial scales.

APPROACH

To achieve the objective of improved confidence in repository processes, investigations are underway to study where analogous processes have occurred in the past or are now taking place. The natural analog studies combine approaches that utilize literature surveys and modeling in conjunction with data from a number of sites world wide to understand flow and transport in unsaturated and saturated environments and the effect of thermal perturbations on the natural system. These include a field and modeling study at Peña Blanca, Mexico, as an analog to radionuclide transport in unsaturated ash flow tuffs and modeling studies of anthropogenic analog sites in the United States to gain a better understanding of plume dispersion, colloidal transport of Pu and fracture/matrix interactions.

The Nopal I uranium deposit at Peña Blanca, Mexico, lies in unsaturated tuffs closely similar in composition to the Topopah Spring Tuff at Yucca Mountain. Previous investigators suggested that downward migration of uranium from the ore deposit has been minimal. We are testing this hypothesis and working to determine the timing and nature of events that caused uranium to migrate away from the ~8 Ma ore deposit. Transport of uranium has been almost entirely along major fractures (on the order of 0.5 cm aperture) with minor transport along microfractures, and almost no matrix diffusion. The majority of our uranium-series data indicate that the system has been closed to uranium migration for the past 300 k.y.

Sites with contaminant plumes allow study of plume migration over time as well as radionuclide transport and retardation mechanisms. Although the anthropogenic sites have a much shorter history than natural analogs, their initial conditions are usually better known and some have been closely monitored. The goal is to utilized experience from modeling flow and transport at sites, such as the Idaho National Engineering and Environmental Laboratory, where flow has occurred along preferential pathways, to build confidence in approaches to modeling flow and transport processes at Yucca Mountain.

Geothermal analogs may provide useful insights into complex coupled thermal-hydrologic-mechanical-chemical processes. We are using data and analyses from selected geothermal fields to obtain added confidence in expected thermohydrologic conditions at Yucca Mountain, particularly those related to dissolving or precipitating minerals to cause changes in fracture permeability.

ACCOMPLISHMENTS

Box Canyon was chosen to test the dual permeability modeling approach used at Yucca Mountain. Numerous air permeability and infiltration tests were used to calibrate the model. The dual permeability representation of the variably saturated, fractured basalt produced infiltration front arrival times that were consistent with bromide tracer data. Calibration parameters included a fracture-matrix interaction scaling factor and fracture continuum porosity. Parameter values were within similar ranges observed at Yucca Mountain despite differences between basalt and tuff, indicating the utility of the dual permeability approach. We are applying data from a plume at INEEL to build understanding of retardation of ^{237}Np, ^{236}U, ^{129}I, and ^{99}Tc, radionuclides that are also of interest at Yucca Mountain.

SIGNIFICANCE OF FINDINGS

Analogs have been identified for a variety of processes expected to occur at the potential nuclear waste repository at Yucca Mountain. These provide a significant bound for numerical modeling and understanding of the effects of these processes; however, since the temporal and spatial conditions of the analogs differ from repository conditions, results are interpreted with caution.

RELATED PUBLICATIONS

Civilian Radioactive Waste Management System, Natural analogs for the unsaturated zone, ANL-NBS-HS-000007, Rev. 00, 2000.

Civilian Radioactive Waste Management System, Yucca Mountain Site Description, Rev. 1.: Section 13, Natural Analogs, in press.

ACKNOWLEDGMENTS

This work was supported by the Director, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, through Memorandum Purchase Order EA9013MC5X between TRW Environmental Safety Systems, Inc., and Ernest Orlando Lawrence Berkeley National Laboratory for the Yucca Mountain Site Characterization Project under Contract No. DE-AC03-7zF00098.